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Macrolichen biomass in Nanda Devi Biosphere Reserve, Chamoli District, Uttarakhand, India

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ABSTRACT

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The lichen biomass in eight localities of Nanda Devi Biosphere Reserve was estimated in 1 x 1 m^2 quadrate. A total of eighty quadrates (ten quadrates at each locality) were laid randomly. Lata, Valley of Flowers and Malari localities, situated in lower altitudes (<3000 m) having anthropogenic pressure, have less lichen biomass than the localities situated in undisturbed higher temperate and alpine regions (>3000 m). In lower altitude localities, 29 species belonging 16 genera of parmelioid lichens (*Evernia, Flavopunctelia, Parmotrema, Parmelia* and *Usnea*) contribute maximum in the production of biomass in most of the localities followed by 13 species belonging to 4 genera of physcioid lichens (*Heterodermia* and *Physcia*). The higher temperate regions between altitudes of 3000-3300 m, having dense mixed coniferous forest, exhibit maximum biomass of lichens represented by 6.144 g/m^2. *Betula utilis, Rhododendron* (3300-3600 m), having short-shrubby trees, also exhibit higher biomass of lichens represented by 5.299 g/m^2. The open exposed areas of Malari, Joshimath and Ghangaria (Valley of Flowers), having scattered thinned out forest with anthropogenic pressure, have poor biomass of lichens. The cyanolichens exhibit poor representation in the biomass and range from 0.013 to 0.844 g/m^2 in undisturbed localities while the disturbed localities exhibit complete absence of the cyanolichens. The Belta area, with thick moist coniferous forest, has rich diversity of lichens represented by 35 species together with highest biomass among all the eight localities studied.

Key-words: Biomass, epiphytic lichen, litter fall, macrolichen, Nanda Devi Biosphere Reserve, Chamoli District, Uttarakhand, India.

INTRODUCTION

The Nanda Devi Biosphere Reserve lies between 30°16' and 30°41' N latitudes and 79°40' and 80°05' E longitudes over an area of 2236.74 km^2. The varied topography and climate of the area provide suitable condition for growth of different plant groups including lichens. The mixed oak and coniferous forests in temperate and subalpine areas form the major forest vegetation. Both phorophytes bear luxuriant growth of epiphytic lichens on their trunk, branches and twigs that contribute significantly in the litter fall biomass on the forest floor.

Lichens occur in most terrestrial ecosystems of the world, but their contribution to the terrestrial biomass varies from insignificant to major. Because most lichens grow relatively slow, their primary productions are fairly small in most ecosystems.

The more rapidly growing species may increase their biomass by 20-40% in a year and these species may play an important role in the mineral cycling pattern of their ecosystem, particularly if cyanolichens are the dominant component (Hofstende et al. 1993, Hsu et al. 2002).

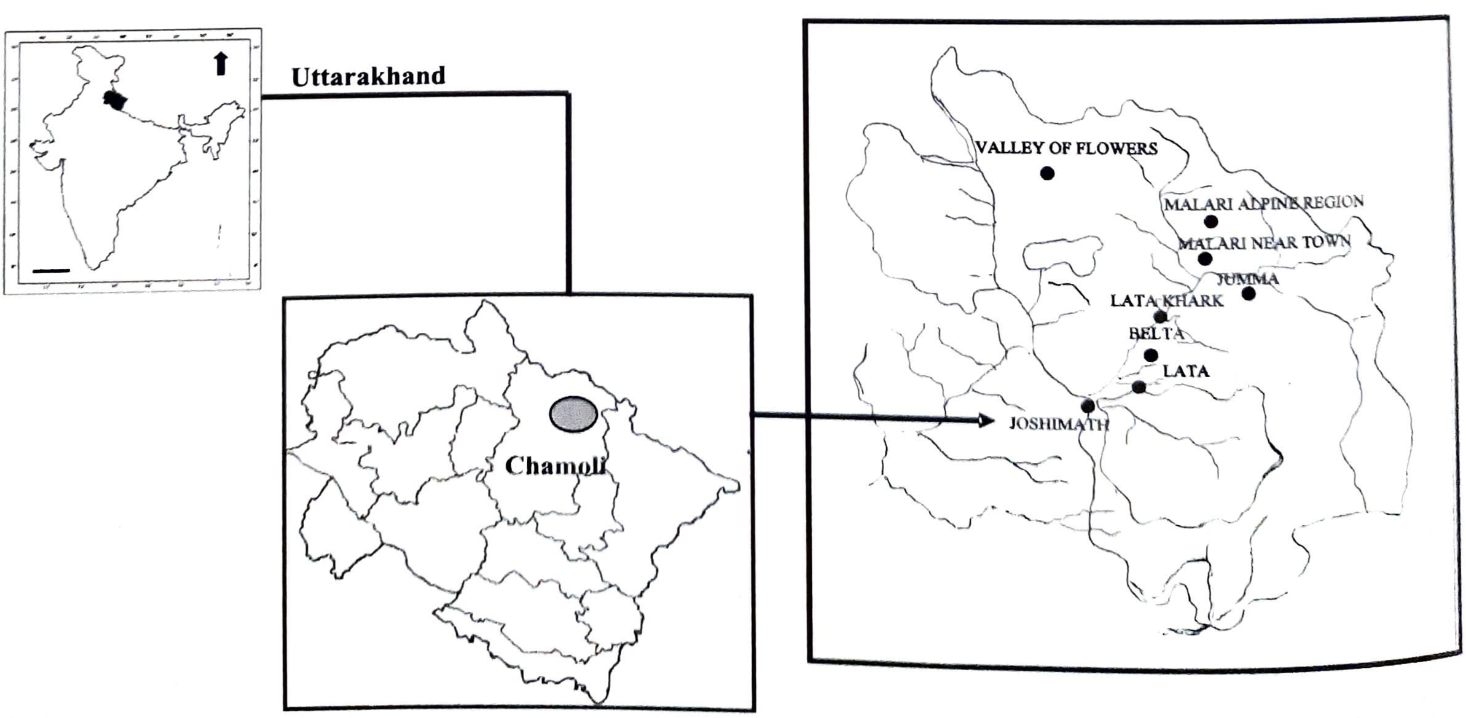
India, being a mega-biodiversity region of the world, has rich lichen diversity together with other plant groups. The lichens grow luxuriantly in the Himalayas, particularly the higher altitudes of Kumaun and Garhwal Himalayas. More than 1200 lichen species are known from the Himalayas, of which 700 species are known from Uttarakhand (Upreti & Joshi 2010). A number of taxonomic studies pertaining to the lichens of the Himalayas are available. However, information on ecology and lichen biomass in this area is rather meagre (Upreti & Negi 1995, Negi & Gadgil 1996, Upreti & Chatterjee 1999, Negi 2001, Rawat et al. 2011).

According to Berryman and McCune (2006), biomass models provide a useful tool for describing and understanding the distribution of epiphytic macrolichen abundance at landscape scales (the spatial or temporal measure of an object or process). Biomass estimates are important for understanding lichen function at a landscape level. Furthermore, models for estimating lichen biomass can be used to assess probable consequences of alternative management strategies (Cissel et al. 1999) by forecasting future biomass distribution in the landscape based on changes in forest structure (Dettki & Esseen 2003).

Except for preliminary biomass data of three temperate forests of Chamoli District (Rawat et al. 2011), no records of lichen litter fall from the Himalayas are available. Thus the present study is initiated with an aim to assess the lichen biomass distribution in different temperate and alpine regions of Uttarakhand, together with the factors which influence the lichen biomass in this region.

MATERIAL AND METHODS

Study area: The study area includes Joshimath (1700 m), Lata (2800 m), Malari (3000 m), Jumma (3100 m), Valley of Flowers (3000 m), Belta (3300 m), Malari (3400 m) and Lata Kharak (3600 m)



Text-figure 1. Localities of Nanda Devi Biosphere Reserve for lichen biomass analysis.

in Nanda Devi Biosphere Reserve (NDBR). The localities were surveyed for recording the lichen litter fall biomass during June to October in 2007 and 2008. The coniferous trees form the major vegetation in the area sometimes forming pure patches or mixed with other trees. Belta, Valley of Flowers and Malari forests exhibit dominance of coniferous trees, such as *Abies pindrow* (Royle ex D. Don) Royle, *Pinus wallichiana* A. B. Jacks, *Taxus baccata* L. and *Cedrus deodara* (Roxb.) Loud., together with *Betula utilis* D. Don. Lata Kharak and Malari forest alpine region have coniferous trees in association with *Rhododendron companulatum* D. Don. Lata, Jumma and Joshimath forest have pure patches of *Pinus wallichiana* A. B. Jacks.

Size and number of plots, sampling and sample preparation: At each of the study site, ten quadrates of 1 x 1 m^2 were randomly laid on forest floor. Macrolichens fallen from trees were collected for analysis. The collected samples were segregated and identified up to their species level based on their morphological, anatomical and chemical features using Indian lichen literature (Awasthi 1988, 2000, Divakar & Upreti 2005). The lichen substances of the collected lichen specimens were identified by colour spot tests (K, C, Pd) following the technique of Walker & James (1980) for thin layer chromatography (TLC) using the solvent system A (Toluene: 1-4 dioxane: Acetic acid: 180: 60: 8 ml). The lichens were weighed after removing the twigs or any other foreign material and completely dried in oven at 70° C (Stephen & Sillett 1995).

RESULTS AND DISCUSSION

Identification of the lichen biomass samples collected from the eighty plots of the study area resulted into 82 lichen species belonging to 39 genera and 16 families (Tables 1, 2). The members of lichen family Parmeliaceae (parmelioid) exhibit dominance in the biomass of most of the sites (Table 3). A total of 29 species belonging to 15 genera of parmelioid lichens were present in the biomass which contributes more than 50% of the biomass (Table 3). The maximum biomass of 6.144 gm/m^2 was recorded from the Belta site followed by Lata Kharak with 5.299 gm/m^2, Malari near town with 4.642 gm/m^2 and Jumma 3.887 gm/m^2. The study area exhibits poor lichen biomass in Valley of Flowers (0.421 gm/m^2), Malari alpine (0.459 gm/m^2), Joshimath (1.275 gm/m^2), and Lata (1.61 gm/m^2) (Table 3). The sites studied for the lichen biomass have variation in microclimatic condition, altitudes and forest vegetation together with anthropogenic activities which influenced the litter fall biomass up to a great extent. The different biotic and abiotic factors responsible for lichen litter fall biomass in the area are given below.

Anthropogenic pressure: The human activities, either external or internal, influenced the ecosystem of the forest health. The lichen biomass estimation in Valley of Flowers area, situated at an altitude of 3000 m, shows quite low biomass of 0.421 gm/m^2 (Table 3). The members of parmelioid lichens *Punctelia borreri, Parmotrema nilgherrense* and *Punctelia subrudecta* contribute maximum in the litter fall biomass. Being a famous tourist place and holy pilgrimage, Valley of Flowers and Hemkund Saheb receive a large number of tourists throughout the year. The horses and mules are the major means of transport. Around 3000 horses and mules are used for transportation and for carrying goods to Hemkund and Valley of Flowers (Farooquee et al. 2008). Since the tourists follow different trekking routes, often using short-cuts, they destroy the lichen biomass (accumulated after falling from the trees or naturally growing on the ground) unknowingly on forest floor by

Table 1. Macrolichen biomass gm/m² in different localities of Nanda Devi Biosphere Reserve (NDBR). AV = Average biomass, Q = Quadrate, Site 1: Lata, 2800 m/pure patches of *Pinus wallichiana* A. B. Jacks.; Site 2: NDBR, 3600 m/*Rhododendron companulatum* D. Don.

Lichen Taxa	Site 1, Quadrate 1 to 10											Site 2, Quadrate 1 to 10										
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	AV	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	AV
Caliciaceae																						
Pyxine himalayana D. D. Awasthi																						
Pyxine cocöes (Swartz) Nyl.																						
Pyxine himalayensis D. D. Awasthi																						
Pyxine subcinerea Stirton																						
Candelariaceae																						
Candelaria concolor (Dicks.) B. Stein																0.36						**0.036**
Cladoniaceae																						
Cladonia ochrochlora Flörke																	0.03					**0.003**
Cladonia pyxidata (L.) Hoffm.																						
Collemataceae																						
Leptogium burnetii Dodge																						
Leptogium saturninum (Dickson) Nyl.																						
Graphidaceae																						
Pheographis sp.																						
Lobareaceae																						
Lobaria pindarensis Räsänen																						
Lobaria retigera (Bory) Trevisan																						
Parmeliaceae																						
Bryoria smithii (Du Rietz) Brodo & D. Hawksw.																						
Cetrelia cetrarioides (Del.ex Duby) W. Culb.& C.Culb.	0.02				0.10			0.04		0.01	**0.017**	2.02		0.97		1.03	0.42		0.26	0.22		**0.492**
Evernia mesomorpha Nyl.	0.50								0.09		**0.059**	3.15	0.05			0.07	3.22	3.05	0.05	0.09	0.14	**0.982**
Evernia prunastri (L.) Ach.																	0.34					**0.034**
Everniastrum cirrhatum (Fr.) Hale ex Sipaman	0.10				0.01						**0.011**											
Flavoparmelia caperata (L.) Hale		0.49				0.18			0.20		**0.087**					0.11						**0.011**
Flavopunctelia flaventior (Stirton) Hale		1.5				0.06		0.02	1.08		**0.266**		0.03	0.06		0.30	0.44		0.31		0.53	**0.167**
Flavopunctelia soredica (Nyl.) Hale			1.02								**0.102**	3.51	0.06	0.06		3.6	0.45					**0.768**
Melanelia heptizone (Ach.) Thell																						
Myelochroa aurulenta (Tuck.) Elix & Hale																						
Parmelia sulcata Taylor																						

Parmelaria subthomsonii D. D. Awasthi																	1.68		0.78		**0.246**
Parmotrema nilgherrense (Nyl.) Hale													0.07				0.04					**0.011**
Parmotrema pseudonilgherrense (Asahina) Hale																						
Parmotrema reticulata (Taylor) M. Choisy					0.27		0.20				**0.047**											
Parmotrema tinctorium (Nyl.) Hale																						
Punctelia ruducta (Ach.) Krog																						
Punctelia subruducta (Nyl.) Krog																						
Usnea himalayana G. Awasthi												0.04					0.10	0.38			0.41	**0.093**
Usnea longissima Ach.												1.13	0.07			1.88	1.69	2.72	1.71	2.59	1.15	**1.294**
Usnea orientalis Mot.		0.33		1.78			1.15		0.01	0.10	**0.337**	0.34	2.23			0.01	0.05	0.35	0.64			**0.362**
Usnea perplexans Stirton																						
Usnea subflorida Stirton													0.29				0.38			0.55		**0.122**
Peltigeraceae																						
Peltigera praetextata (Flörke ex Sommerf.) Vain.																				1.02		**0.102**
Peltigera rufescens (Weiss) Humb.																						
Physciaceae																						
Hetrodermia albidoflava (Kurok) Awasthi																						
Heterodermia cosmosa (Eschw.) Follman & Redon																						
Heterodermia diademata (Taylor) D. Awasthi				0.22							**0.022**	0.02										**0.002**
Heterodermia leucomela (L.) Poelt												0.01									0.04	**0.005**
Heterodermia pseudospeciosa (Kurok.) W. Culb.																						
Heterodermia speciosa (Wulfen) Trevisan																						
Phaeophyscia hispidula (Ach.) Moberg	0.90		0.05					0.02		0.55	**0.152**				0.03							**0.003**
Physcia stellaris (L.) Nyl.												0.14	0.05		0.03						0.02	**0.024**
Physcia tribacia (Ach.) Nyl.																						
Physconia detersa (Nyl.) Nyl.		0.01		0.41			0.20				**0.062**											
Ramaliaceae																						
Ramalina conduplicans Vainio	0.55				1.53			0.40		1.04	**0.352**	0.24				2.73	0.06				0.04	**0.307**
Ramalina hossie Vain.																			0.51	0.16		**0.067**
Ramalina roesleri (Hochst ex Schaer.) Hue		0.01			0.05		0.01		0.11		**0.018**	0.04		0.07	0.08						0.01	**0.002**
Ramalina sinensis Jatta	0.01	0.20				0.28	0.07		0.01		**0.057**		0.28			0.28		0.42	0.27		0.40	**0.165**
Teloschistaceae																						
Xanthoria elegans (Link.) Th. Fr.																					0.01	**0.001**
Xanthoria perietina (L.) Th.Fr.			0.20						0.01		**0.021**											
Total (g m^{-2})											**1.61**											**5.299**

Table 1 (Continued). **Site 3: NDBR, 3300 m/*Abies pindrow* (Royle ex D. Don.) Royle and *Pinus wallichiana* A. B. Jacks., *Taxus baccata* L. and *Cedrus deodara* (Roxb.) Loud., together with *Betula utilis* D. Don.; Site 4: Joshimath, 1700 m/ pure patches of *Pinus wallichiana* A. B. Jacks.**

Lichen Taxa	Site 3, Quadrate 1 to 10											Site 4, Quadrate 1 to 10										
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	AV	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	AV
Caliciaceae																						
Pyxine himalayana D. D. Awasthi					2.41						0.241											
Pyxine cocöes (Swartz) Nyl.																**0.05**						**0.037**
Pyxine himalayensis D. D. Awasthi															**0.05**							**0.005**
Pyxine subcinerea Stirton																	**0.09**	**0.03**	**0.14**			**0.026**
Candelariaceae																						
Candelaria concolor (Dicks.) B. Stein																						
Cladoniaceae																						
Cladonia ochrochlora Flörke																						
Cladonia pyxidata (L.) Hoffm.	0.72				0.41	0.25					**0.138**											
Collemataceae																						
Leptogium burnetii Dodge	0.02					1.27					**0.129**											
Leptogium saturninum (Dickson) Nyl.			0.55								**0.055**											
Graphidaceae																						
Pheographis sp.	0.01										**0.001**											
Lobareaceae																						
Lobaria pindarensis Räsänen			0.81							0.44	**0.125**											
Lobaria retigera (Bory) Trevisan	0.69			0.50	0.10				0.37		**0.166**											
Parmeliaceae																						
Bryoria smithii (Du Rietz) Brodo & D. Hawksw.					0.04						**0.004**											
Cetrelia cetrarioides (Del.ex Duby) W. Culb.& C.Culb.	2.84	9.00	1.03			3.90	3.12	2.18	2.27	2.55	**2.689**											
Evernia mesomorpha Nyl.	0.56	0.33		0.02		0.07		0.26			**0.124**											
Evernia prunastri (L.) Ach.																			**0.08**		**0.32**	**0.040**
Everniastrum cirrhatum (Fr.) Hale ex Sipaman					0.11						**0.011**											
Flavoparmelia caperata (L.) Hale	0.08										**0.008**						**0.15**	**0.08**		**0.04**		**0.027**
Flavopunctelia flaventior (Stirton) Hale	0.22	0.02			0.02				0.05	0.47	**0.078**											
Flavopunctelia soredica (Nyl.) Hale	0.23		0.05			0.07	0.05			0.37	**0.077**											
Melanelia heptizone (Ach.) Thell																**0.70**						0.07
Myelochroa aurulenta (Tuck.) Elix & Hale												**0.45**		**0.07**				0.72			0.30	0.154
Parmelia sulcata Taylor												0.61							0.21			0.082
Parmelaria subthomsonii D. D. Awasthi																						

Parmotrema nilgherrense (Nyl.) Hale									0.37	0.13	**0.050**											
Parmotrema pseudonilgherrense (Asahina) Hale															**0.23**						**0.59**	**0.082**
Parmotrema reticulata (Taylor) M. Choisy			0.04	3.24							**0.328**			**0.05**	**0.45**				**0.16**	**1.94**		**0.216**
Parmotrema tinctorium (Nyl.) Hale															**0.15**					**0.5**		**0.065**
Punctelia ruducta (Ach.) Krog												**0.02**	**0.02**		**0.06**					**0.14**	**0.09**	**0.033**
Punctelia subruducta (Nyl.) Krog							0.07				**0.007**											
Usnea himalayana G. Awasthi								0.01			**0.001**											
Usnea longissima Ach.		1.77	0.88	0.53	0.80	0.62	0.83	0.38	1.42	0.42	**0.765**											
Usnea orientalis Mot.			0.07					0.24			**0.031**											
Usnea perplexans Stirton																			**0.02**			**0.002**
Usnea subflorida Stirton								0.12	0.11	0.02	**0.025**											
Peltigeraceae																						
Peltigera praetextata (Flörke ex Sommerf.) Vain.	0.69					1.35					**0.204**											
Peltigera rufescens (Weiss) Humb.						1.49			0.16		**0.165**											
Physciaceae																						
Hetrodermia albidoflava (Kurok) Awasthi													**0.36**									**0.036**
Heterodermia cosmosa (Eschw.) Follman & Redon																	**0.12**					**0.012**
Heterodermia diademata (Taylor) D. Awasthi					0.02	0.20					**0.022**	**0.72**	**0.23**		**0.19**	**0.23**		**0.25**	**1.1**	**0.41**	**0.48**	**0.361**
Heterodermia leucomela (L.) Poelt		0.10	0.30		0.10		0.22	0.12	0.16	0.07	**0.107**											
Heterodermia pseudospeciosa (Kurok.) W. Culb.								0.55			**0.055**											
Heterodermia speciosa (Wulfen) Trevisan															**0.08**							**0.008**
Phaeophyscia hispidula (Ach.) Moberg		0.06							0.03		**0.009**			**0.17**								**0.017**
Physcia stellaris (L.) Nyl.	0.03										**0.003**											
Physcia tribacia (Ach.) Nyl.										0.20	**0.020**				**0.02**							**0.002**
Physconia detersa (Nyl.) Nyl.										0.28	**0.028**											
Ramaliaceae																						
Ramalina conduplicans Vainio											**0.213**											
Ramalina hossie Vain.	1.94							0.06	0.13		**0.036**											
Ramalina roesleri (Hochst ex Schaer.) Hue				0.22						0.14	**0.066**											
Ramalina sinensis Jatta		0.11		0.01	0.02	0.43	0.09															
Teloschistaceae																						
Xanthoria elegans (Link.) Th. Fr.	0.20										**0.020**											
Xanthoria perietina (L.) Th.Fr.	0.43										**0.143**											
Total (g m^{-2})											**6.144**											**1.275**

Table 2. Macroichen biomass gm/m² in different localities of Nanda Devi Biosphere Reserve (NDBR). AV = Average biomass, Q = Quadrate. Site 5: Malari, 3400 m/*Rhododendron companulatum* D. Don.; Site 6: Malari, 3000m/*Abies pindrow* (Royle ex D. Don) Royle, *Pinus wallichiana* A. B. Jacks, *Taxus baccata* L. and *Cedrus deodara* (Roxb.) Loud., together with *Betula utilis* D. Don.

Lichen Taxa	Site 5, Quadrate 1 to 10											Site 6, Quadrate 1 to 10										
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	AV	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	AV
Cladoniaceae																						
Cladonia pyxidata (L.) Hoffm.													0.08	0.02	0.01							**0.011**
Collemataceae																						
Leptogium denticulatum Nyl.																						
Leptogium saturninum (Dickson) Nyl.																						
Lobariaceae																						
Lobaria pindarensis Räsänen																						
Lobaria sp.																						
Parmeliaceae																						
Canoparmelia sp.																						
Evernia mesomorpha Nyl.												0.06			0.02							**0.008**
Evernia pruunastri (L.) Ach.	0.18	2.20			0.49	0.55	0.08	0.18	1.25	0.59	**0.552**								0.01			**0.001**
Everniastrum cirrhatum (Fr.) Hale ex Sipaman																						
Flavoparmelia caperata (L.) Hale		0.64						0.97		0.12	**0.173**											
Flavopunctelia flaventior (Stirton) Hale		0.88			0.08	1.66	0.12		0.50		**0.324**								0.03			**0.003**
Flavopunctelia soredica (Nyl.) Hale	0.19				0.04		0.15				**0.038**											
Melanelia hepatizone						0.28		0.53		0.15	**0.096**								0.01	0.05		**0.006**
Parmelaria thomsonii (Stirton) D. Awasthi						0.02					**0.002**											
Parmelia sulcata Taylor																	0.08					**0.008**
Parmelinella wallichiana (Taylor) Elix & Hale																						
Parmotrema nilgherrense (Nyl.) Hale																						
Parmotrema reticulata (Taylor) M. Choisy																						
Parmotrema tinctorum (Nyl.) Hale						0.02					**0.002**											
Punctelia borreri (Sm.) Krog																						
Punctelia ruducta (Ach.) Krog																						
Punctelia subrudecta (Nyl.) Krog																						
Rimelia reticulata (Taylor) Hale & Fletcher					0.25			0.01			**0.026**	0.14										**0.014**
Rhizoplaca chrysoleuca (Smith) Zopf																						
Usnea orientalis Mot.		0.01									**0.001**											
Usnea nepalensis D. Awasthi ex. G. Awasthi		0.42		0.21	0.03			0.22		0.26	**0.114**	0.05	0.12		0.11	0.02		0.03		0.09		**0.042**
Usnea perplexans Stirton	0.01	0.11	0.03		0.38	0.65	0.07		0.22	0.28	**0.175**	0.33					0.18	0.02	0.03	0.01		**0.057**
Usnea subflorida Stirton			.02								**.002**											
Usnea thomsonii Stirton																						

Physciaceae																						
Heterodermia diademata																						
Heterodermia speciosa (Wulfen) Trevisan																						
Phaeophyscia hispidula (Ach.) Moberg																						
Physcia stellaris (L.) Nyl.	1.79	0.56	1.67	0.69	1.35	0.78	1.06		0.36	2.42	**1.068**			0.01	0.01	0.17	0.10	0.05				**0.034**
Physcia tribacia (Ach.) Nyl.																						
Ramaliaceae																						
Ramalina sinensis Jatta	1.46	2.22	3.79	1.21	1.94	2.53	0.73	0.64	1.79	4.38	**2.069**		2.22		0.29	0.03	0.04	0.02		0.08	0.07	**0.275**
Stereocaulaceae																						
Stereocaulon foliolosum Nyl.																						
Teloschistaceae																						
Xanthoria perietina (L.) Th. Fr.																						
Verrucariaceae																						
Dermatocarpon miniatum (L.) Mann.																						
Total (g m^{-2})											**4.642**											**0.459**

Table 2 (Continued). Site 7: Jumma, 3100 m/*Abies pindrow* (Royle ex D. Don) Royle, *Pinus wallichiana* A. B. Jacks, *Taxus baccata* L. and *Cedrus deodara* (Roxb.) Loud., together with *Betula utilis* D. Don.; Site 8: Valley of Flowers, 3300 m/*Abies pindrow* (Royle ex D. Don) Royle, *Pinus wallichiana* A. B. Jacks, *Taxus baccata* L. and *Cedrus deodara* (Roxb.) Loud., together with *Betula utilis* D. Don.

Lichen Taxa	Site 7, Quadrate 1 to 10											Site 8, Quadrate 1 to 10										
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**AV**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**AV**
Cladoniaceae																						
Cladonia pyxidata (L.) Hoffm.																						
Collemataceae																						
Leptogium denticulatum Nyl.						0.59					**0.059**											
Leptogium saturninum (Dickson) Nyl.												**0.04**									**0.04**	**0.008**
Lobariaceae																						
Lobaria pindarensis Räsänen																**0.05**						**0.005**
Lobaria sp.		4.15									**0.415**											
Parmeliaceae																						
Canoparmelia sp.														**0.3**								**0.03**
Evernia mesomorpha Nyl.	0.18										**0.018**											
Evernia pruunastri (L.) Ach.																		**0.12**				**0.012**
Everniastrum cirrhatum (Fr.) Hale ex Sipaman																						
Flavoparmelia caperata (L.) Hale		2.46		9.44	0.28	2.5	1.67	0.73		3.75	**2.083**											
Flavopunctelia flaventior (Stirton) Hale	0.18		4.23	0.29	1.02		0.08	1.27	2.48		**0.937**											

Flavopunctelia soredica (Nyl.) Hale							0.13			**0.013**											
Melanelia hepatizone																					
Parmelaria thomsonii (Stirton) D. Awasthi																					
Parmelia sulcata Taylor					0.13					**0.013**											
Parmelinella wallichiana (Taylor) Elix & Hale																**0.05**	**0.03**				**0.008**
Parmotrema nilgherrense (Nyl.) Hale													**0.01**	**0.01**		**0.08**					**0.01**
Parmotrema reticulata (Taylor) M. Choisy												**0.16**				**0.06**	**0.08**	**0.26**		**0.15**	**0.071**
Parmotrema tinctorum (Nyl.) Hale																					
Punctelia borreri (Sm.) Krog												**0.08**	**0.13**	**0.11**	**0.09**		**0.02**		**0.46**		**0.089**
Punctelia ruducta (Ach.) Krog									0.01	**0.001**											
Punctelia subrudecta (Nyl.) Krog													**0.52**	**0.01**			**0.09**	**0.03**	**0.06**		**0.071**
Rimelia reticulata (Taylor) Hale & Fletcher																					
Rhizoplaca chrysoleuca (Smith) Zopf												**0.02**									**0.002**
Usnea orientalis Mot.											**0.01**									**0.06**	**0.007**
Usnea nepalensis D. Awasthi ex. G. Awasthi																					
Usnea perplexans Stirton	0.01									**0.001**											
Usnea subflorida Stirton													**0.19**		**0.02**			**0.08**			**0.029**
Usnea thomsonii Stirton																					
Physciaceae																					
Heterodermia diademata								0.15		**.015**											
Heterodermia speciosa (Wulfen) Trevisan														**.03**							**.003**
Phaeophyscia hispidula (Ach.) Moberg		0.02								**0.002**		**0.20**									**0.020**
Physcia stellaris (L.) Nyl.	1.8									**0.18**		**0.15**									**0.015**
Physcia tribacia (Ach.) Nyl.												**0.20**									**0.020**
Ramaliaceae																					
Ramalina sinensis Jatta	1.5									**0.15**		**0.14**									**0.014**
Stereocaulaceae																					
Stereocaulon foliolosum Nyl.																			**0.01**		**0.001**
Teloschistaceae																					
Xanthoria perietina (L.) Th. Fr.					0.01						**0.01**		**0.01**	**0.02**						**0.01**	**0.005**
Verrucariaceae																					
Dermatocarpon miniatum (L.) Mann.											**0.01**										*0.001*
Total (g m^{-2})										**3.887**											***0.421***

Table 3. Dominant lichens and their biomass in each locality.

Areas	Altitudes (m)	Toal lichen species	Biomass of total lichens	Parmelioid lichen species	Biomass of parmelioid lichens	Physcioid lichen species	Biomass of physcioid lichens	Ramalioid lichen species	Biomass of ramaliod lichens	Cyanolichen species	Cyanolichen biomass
Lata	2800	15	1.61	8	0.926	3	0.236	3	0.427	0	0
Belta	3300	35	6.144	14	4.198	8	0.245	4	0.315	6	0.844
Lata Khark	3600	24	5.299	12	4.582	4	0.034	4	0.514	1	0.102
Malari near town	3000	14	4.642	11	1.503	2	1.068	2	2.069	0	0
Malari Alpine	3400	11	0.459	8	0.139	1	0.34	1	0.275	0	0
Jumma	3000	13	3.887	7	3.066	3	0.197	1	0.15	2	0.474
Joshimath	1700	19	1.275	10	0.771	6	0.436	0	0	0	0
Valley of Flowers	3000	19	0.421	9	0.258	4	0.058	1	0.014	2	0.013

trampling of animals. Except for the Valley of Flowers and Malari alpine region areas, having human activities and animal grazing respectively, most of the localities in higher altitudes have higher estimates of biomass than the lower altitudes. *Usnea longissima, Cetrelia cetrarioides*, *Evernia mesomorpha* and *Hetrodermia leucomela* contribute together with *Ramalina sinensis* in the biomass of these areas. The lower altitude (<3000 m) localities have low estimate of biomass ranges from 0.421-1.610 gm/m^2. *Ramalina sinensis* and *Usnea orientalis* are the major constituents of the biomass. As the site is situated near the village and town, the local peoples depend on the forest resources for their daily need of fodder and kitchen fuel. The activities of lopping and pruning of twigs exposed the trunks to sunlight thus largely not only destroys most of the epiphytic lichens on twigs but also reduces the moisture on the trunk which does not allow many lichens to colonize there. Upreti (1995) assessed the different factors responsible for loss of lichen diversity in India. Important factors include the change in the ecological conditions, forest cover, loss of habitat and increase of vehicular traffic, together with increase in urban and industrial areas. The various man made activities in hilly regions of India such as 'Jhoom' cultivation, agriculture, mineral extraction, tourism, hydroelectric and road building projects are other factors leading to the rapid deterioration of lichen rich habitats. The solid waste is increasing at an alarming rate because of the heavy influx of tourists in the Valley of Flowers and Joshimath areas which resulted in the loss of many plant groups including lichens fallen on the forest floor.

Humidity: The coniferous forest with dense, closed canopy of trees provide ample amount of shade and moisture for many shade loving lichens to grow luxuriantly on branches, twigs, trunk and at the base of the trunk. The twigs on top of the canopy provide suitable condition for many light loving lichens. The lichen utilized the stored water and ameliorated humidity by epiphytic mosses during changes in the moisture of canopy. All the four localities, viz. Belta, Lata Kharak, Malari and Jumma town area, having high moisture contents, support abundance of macrolichens on the trees and exhibit higher litter fall biomass on the forest floor represented by 6.144 g/m^2, 5.299 g/m^2 4.642 g/m^2 and 3.887 g/m^2 respectively. A single lichen species *Cetrelia cetrarioides* of the biomass 2.689 gm/m^2 contributes maximum in the biomass at Belta. The presence of cyanolichen in a particular forest indicates a moist, humid and shady habitat. In the studied area, cyanolichens (*Leptogium* and *Lobaria*) exhibit their presence only in localities having moist and shady habitat and contribute a biomass of 0.844 gm/m^2 (Table 3).

Altitude: Altitude is one of the main factors controlling the diversity and distribution of epiphytic lichens (Öztürk & Güvenç 2010). Lata Kharak, Belta and Malari localities (3000-3600 m) have a maximum lichen biomass. Baniya et al. (2010) recorded that the total number of lichens, as well as the number of endemic species in Nepal Himalayas, showed humped relationship with elevation. Their highest richness was observed between 3100 to 3400 m and 4000 to 4100 m respectively. All growth forms showed a unimodel relationship of richness with elevation. The lower altitudes in Joshimath (1700 m) and Lata (2800 m) have low estimate of biomass of 1.275 gm/m^2 and 1.610 gm/m^2 respectively. The members of parmelioid and physcioid groups dominate the biomass as *Parmotrema reticulata* and *Everniastrum cirrhatum*, the two parmelioid lichens, contribute the major part of biomass together with *Heterodermia diademata* (Table 3).

Vegetation: The forest vegetation of a particular site plays important role in biomass composition of that area. The coniferous forest floor exhibits more lichen biomass than the other forests. Since the mixed forest provide diverse substrates to a variety of lichens to colonize, the localities with only *Pinus wallichiana* forest exhibit less lichen biomass than the mixed forest of *Cedrus deodara, Taxus baccata* and *Rhododendron companulatum*. The epiphytic lichen biomass of temperate forests slowly increases with stand age, typically reaching high levels in mature and old-growth forests (McCune 1993) and in stands that are more structurally complex (McCune & Geiser 1997, Clement & Shaw 1999, Pipp et al. 2001). Joshimath and Lata areas, having young tree forest, exhibit low biomass, while Belta, Malari and Jumma, having old growth forest, have higher biomass of lichens.

CONCLUSION

The above account makes it clear that the localities having heavy anthropogenic pressure and young regenerated forest exhibit poor litter fall biomass of macrolichens than the localities having less human activity and mixed old growth forest. The lower altitude at Joshimath and heavy anthropogenic activity at Lata area appear to be the probable reasons for low lichen biomass in both the localities, respectively. The humidity, forest vegetation type and altitude also influenced the biomass of the area up to a great extent. The lichen biomass collected from the forest floor clearly reflects the actual lichen biomass found growing on trees and also growing on ground. Parmelioid lichens are economically important and contribute major part of macrolichen biomass in Nanda Devi Biosphere Reserve. The present record of lichen biomass of different localities in Nanda Devi Biosphere Reserve will act as a base line data to study environmental changes in the area in future.

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